Title: Movement and Physiological demands of Australasian National Rugby League Referees

Submission Type: Original Investigation

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Preferred Running Head: Match demands of NRL referees

Abstract Word Count: 248 words

Text-Only Word Count: 3623 words

Number of Tables: 6

Number of Figures: 0

Abstract

Purpose: To evaluate the movement and physiological demands of the Australasian National Rugby League (NRL) referees, officiating with a 'two referee' (i.e., 'lead' and 'pocket') system and to compare the demands of the lead referee and pocket referees.

Methods: 10 Hz global positioning system devices were used to obtain 86 data sets ('lead', *n*=41; 'pocket', *n*=45) on 19 NRL referees. Total distance, relative distance covered and heart rate per half and across match-play was examined within and between referees using t-tests. Distance, time and number of movement 'efforts' were examined in six velocity classifications (i.e., standing <0.5; walking 0.51–2.0; jogging 2.01-4.0; running 4.01-5.5; high speed running 5.51-7.0; sprinting > 7.0 $m.s^{-1}$) using ANOVA. Cohen's *d* effect sizes were reported.

Results: There were no significant differences between the 'lead' and 'pocket' referee for any movement or physiological variable. There was an overall significant (large; very large) effect for distance (% distance) and time (% time) ($P < 0.001$) between each velocity classification for both the 'lead' and 'pocket' referee. Both roles covered the largest distance and number of efforts at velocities between 0.51–2.0 $m.s^{-1}$ and 2.01-4.0 $m.s^{-1}$, which were interspersed with efforts >5.51 $m.s^{-1}$.

Conclusions: Findings highlight the intermittent nature of rugby league refereeing, but show that there were no differences in the movement and physiological demands of the two refereeing roles. Findings are valuable for those responsible for the preparation, training and conditioning of NRL referees, and to ensure training prepares for and simulates match demands.

Key Words: Match officiating; match demands; intermittent physical demands; heart rate; time-motion analysis.

Introduction

Rugby league (RL) is an intermittent team sport involving bouts of high-intensity physical activity separated by bouts of low speed activity performed over two 40 minute halves.[1] Rugby league referees are an essential part of the game. They are responsible for enforcing the laws of the game, regulating the behaviour of the players, and their decisions can influence the outcome of a game. The European Super League (SL) and Australian National Rugby League (NRL) are the most prominent elite competitions in world rugby league.[2] Global Positioning System (GPS) analysis has become a popular technology for evaluating the movement and physiological demands of sports and there is a growing literature within the area.[2-4] However there is limited research on the movement and physiological demands of rugby league referees with only two SL[5,6] and three NRL studies respectively.[7-9]

A study on NRL referees ('one referee' system) identified that the mean total distance covered during match play was 7607 m [9] with most distance covered (67%; 4651 m) between 0 – 1.94 $m.s^{-1}$ (walking/slow jogging), with 6% (443 m) between 4.72 – 8.33 $m.s^{-1}$ (sprinting). In comparison Kay and Gill [7] found NRL referees ('one referee' system) to cover 6700 ± 400 m with jogging (56%) making up the largest proportion of distance covered, but with 2% consisting of sprinting (movement was categorised based on gait characteristics, no speed thresholds were provided). Mean distance covered by SL referees during match play has been reported to be 7114 ± 748 m [6], consisting of 200 ± 149 m (2.8%) at a running speed > 5.51 $m.s^{-1}$. O'Hara et al [5] found a total distance covered of 8951 ± 746 m with the greatest distance covered between 2.01 – 4.0 $m.s^{-1}$ (42%; 3717 m), but with a calculated distance of 5% (515 m) > 5.51 $m.s^{-1}$. Together, these studies indicate that NRL and SL refereeing consists of bouts of high intensity activity, interspersed with periods of low intensity exercise. The relative distance covered by SL referees has been reported to be 77.9 ± 9.6 [6] and 104.8 ± 10.0 $m.min^{-1}$. [5] However, it is not possible to conclude if this large difference is of practical importance as the data was collected using different sampling frequency GPS devices, 10 Hz and 5 Hz respectively. Similar relative heart rates 79 – 84 $\%HR_{max}$ during match play [6,8,9] have also been reported for both NRL and SL referees.

Comparisons between the running demands of NRL and SL referees is problematic given studies utilised GPS devices with different sampling frequencies or time motion analysis methods (i.e., video analysis). Moreover, studies of NRL referees used only 1 Hz GPS devices [9] and video analysis [7], which have poorer validity and inter-unit reliability than GPS devices with higher sampling frequencies. [10,11] Utilising GPS devices with lower

sampling frequencies (1 Hz and 5 Hz) could provide an inaccurate estimation of the external load of referees, therefore preventing coaches and conditioning staff from accurately conditioning referees to the demands of match play. [11] Therefore, to better understand the movement demands of NRL referees, studies should employ 10 Hz GPS devices.

Historically, rugby league games have been officiated by a single on-field referee, supported by two touch judges, and more recently a video referee. The referee has to control the 10 m defensive line whilst positioning themselves in the best possible place to make a decision. However, in 2009 the NRL adopted a 'two referee' system. Anecdotally, the aim of this policy was to reduce the physical stress of the game on single referees, and to help try and ensure better decision making in the game. Within the NRL, the 'lead' referee assumes the more traditional role of holding the 10 m defensive line and controlling play, whilst the assistant referee ('pocket' referee) monitors the 'play-the-ball', sitting in the space (i.e., 'pocket') behind the attacking team's ruck. The 'two referee' system is also associated with experience. Typically more experienced referees adopt the 'lead' role for approximately 80% of the game, and the 'pocket' for 20%; whilst the other less experienced referee acts as the 'pocket' and 'lead' for 80% and 20% respectively. Due to the role of the 'pocket', positioned behind the ruck following play, this role was believed to cover a greater distance within a game. However, to date no research directly evaluating the physical and movement demands of Rugby League referees using the 'two referee' system has been undertaken to confirm this. This study therefore seeks to be the first and most comprehensive analysis of the movement and physiological demands of the NRL 'two referee' system utilising 10Hz global positioning system (GPS) devices.

The aims of this study were to evaluate the movement and physiological demands of the NRL referees officiating with a 'two referee' system using 10Hz GPS devices and to compare the demands of the 'lead' and 'pocket' referee. It was hypothesised that the 'pocket' referee would cover the greater distances during a game when compared to the 'lead' referee due to the requirements of following play behind the ruck.

Materials & Methods

Subjects

Nineteen NRL referees participated in this study. Eleven referees officiated as the 'lead' referee (age 38 ± 3.5 years; stature 177.6 ± 6.1 cm; body mass 81.3 ± 8.7 kg) and fourteen as the 'pocket' referee (age 35 ± 2.9 years; stature 178.0 ± 6.2 cm; body mass 79.5 ± 9.5 kg). Therefore, 6 referees acted as both a 'lead' and 'pocket' referee. All referees were given detailed information on

the procedures and gave written informed consent. Institutional ethics approval in the spirit of the Helsinki Declaration, was granted and permission to undertake the research was granted by the National Rugby League (NRL) General Manager of Football Operations.

Design

Time-motion analysis was undertaken on a total of 45 NRL domestic matches during the 2013 NRL season using portable 10Hz GPS devices (MinimaxX S4; Catapult Sports, Australia: 88x50x19 mm in size, 67 g in weight) which include tri-axial accelerometers sampling at 100 Hz. The 10 Hz GPS devices (Catapult Sports, Australia) have been reported to be valid and reliable [4] and it has been reported that 10 Hz GPS devices are two to three times more accurate than 5 Hz devices.[12] Heart rate monitors (Polar Electro, Kempele, Finland) were also worn by referees in those matches. Data were collected from Round 5 of NRL competition up to and including the Grand Final. Eleven referees officiated as the 'lead' referee, and fourteen as the 'pocket' ('lead' only $n = 5$; pocket only $n = 8$; both $n = 6$) across data collection. The referee's previous games experience ranged from 2 ($n = 2$ referees) to 278 games, with 'leads' and 'pockets' typically having refereed on average 133 ± 74 and 58 ± 59 games respectively, by the start of the 2013 season. Data for the entire rugby league match were recorded for 'lead' referees on 41 occasions and the 'pocket' for 45 occasions. There was a mean of 3.7 ± 2.4 matches per 'lead' referee and 3.2 ± 2.4 matches per 'pocket' referee. Data was collected on the 'lead' and 'pocket' referee for the same match on 39 occasions. Discrepancies in the number of matches reported to those recorded is due to exclusion of GPS data in cases where the 'lead' ($n = 6$) or 'pocket' referee ($n = 2$) did not activate or wear the unit, there was no or poor satellite coverage, or battery failure.

Procedures

Referees were fitted with a vest, which housed a GPS device between the scapulae. On match day, prior to warming up, referees activated the GPS device. The heart rate monitor was positioned around the chest underneath the GPS vest, with the referee's shirt worn over the top. Referees were familiar with wearing the GPS devices and heart rate monitors during matches, due to both piloting and briefing information.

For all matches the number of satellites ranged from 10 to 13 (11.2 ± 1.0) with a horizontal dilution of precision of 1.8 ± 0.8. A low value (within the range 0-50) for the horizontal dilution of precision indicates an optimal geometrical positioning of orbiting satellites for accurate monitoring of position.[4,13] Total distance (m), relative distance covered ($m.min^{-1}$), and percentage of match heart rate maximum ($\%HR_{max}$) during match play and

per half were examined. Movement was categorised into six velocity classifications according to prior criteria.[14] These were standing (< 0.5 $m.s^{-1}$), walking (0.51 - 2.0$m.s^{-1}$), jogging (2.01 - 4.0 $m.s^{-1}$), running (4.01 - 5.5 $m.s^{-1}$) high speed running (5.51 - 7.0 $m.s^{-1}$; HSR) and sprinting (> 7.0 $m.s^{-1}$). Such velocity classifications were deemed appropriate as they've been previously applied in time motion analyses of Rugby League referees [5] and rugby league players.[15] Even though these qualitative descriptors have different relative meaning to the range of velocities that can be achieved by each referee, the selected absolute velocity classifications were deemed appropriate as they allowed comparison with the literature. However as the qualitative descriptive may be potentially confusing, the absolute velocity classifications were used throughout the reporting and discussion of findings. In each velocity classification, total mean distance, percentage distance, time (minutes), percentage time, and the mean number of movement 'efforts' were examined. An 'effort' is when the referee has entered a velocity zone and remains in the zone for at least 1 second. The distance of 'efforts' within the velocity classification was examined using four predefined distances, as classified by the Catapult Sprint software, 0 - 5 m, 5.01 - 10 m, 10.01 - 40 m and > 40 m.

Heart rate data was not included and examined if heart rate was lost during the match or if there was no corresponding GPS data resulting in 29 'lead' (from n = 10 referees) and 30 'pocket' (from n = 12 referees) heart rate data sets. A referee's heart rate maximum was the peak heart rate achieved during match play and this value was used to calculate relative heart rate intensities, a method used within the literature. [6,16] All data was downloaded to a PC and analysed using Catapult Sprint 5.1.2 (Catapult Innovations, Australia) software and once appropriately formatted for data management it was exported to Microsoft Excel (Microsoft Corporation, USA).

Statistics

Due to the uneven number of matches per referee to reduce bias, each referee's data mean was used to calculate 'lead' and 'pocket' means and were used for statistical analysis. Preliminary assessments checked for violations of normality using Kolomgorov-Smirnov and homogeneity of variances using Levene's test. Then, independent t-tests were used to assess differences between the 'lead' and 'pocket' referee on the movement and physiological variables. A paired samples t-test within each group of referee ('lead' and 'pocket') assessed for differences between the first and second half for physiological and movement demands. A one-way repeated measures analysis of variance (ANOVA) with Bonferroni *post-hoc* procedure assessed for differences between velocity classifications within

each group of referees. Data are reported as mean ± standard deviation. Statistical significance was set at $P < 0.05$ and Cohen's *d* effect size (ES) was reported using a modification to the effect size scale of Cohen.[17] The magnitude of the effect size was classified as; trivial < 0.2, small 0.21 - 0.6, moderate 0.61 - 1.2, large 1.21 - 1.99, and very large > 2.0.[18]

Results

Total and relative distance covered

The total distances covered in match play ranged from 5462 to 8536 m, and 6770 to 8675 m for the 'lead' and 'pocket' referee respectively. There were no significant differences (trivial and small ES) between the mean distance covered by the 'lead' and 'pocket' in the first half, second half, or in total match play (Table 1). The relative distance covered in match play ranged from 62.0 to 89.5 $m.min^{-1}$ and 75.7 to 96.7 $m.min^{-1}$ for the 'lead' and 'pocket' referee respectively. There were no significant differences (small ES) in the relative distance covered by the 'lead' and 'pocket' referee in total match play, or in the first or second half (Table 1).

No significant differences (trivial and small ES) were found between the mean distance and relative distance covered in the first half when compared to lower distances in the second half (Table 1) for the 'lead' ($P = 0.469$, $d = 0.17$ and $P = 0.080$, $d = 0.47$ respectively) and 'pocket' ($P = 0.880$, $d = 0.03$ and $P = 0.053$, $d = 0.48$ respectively) referee.

The 'pocket' referee covered a significantly (moderate ES) higher distance at 0.51 - 2.0 $m.s^{-1}$ in the second half when compared to the first half (Table 2). There were no further significant differences ($P > 0.05$; trivial and small ES) found between the first and second half distance covered at each movement velocity classification for the 'lead' and 'pocket' referee independently. The 'lead' and 'pocket' referee covered less distance at 5.51 - 7.0 $m.s^{-1}$ (small and moderate ES respectively) in the second half when compared to the first half.

Heart rate responses

There were no significant differences between referee roles for $\%HR_{max}$ in the first half and second half even though the 'pocket' referee had a higher $\%HR_{max}$ in the first half compared to the 'lead' referee (moderate ES). The $\%HR_{max}$ for total match play was similar for the 'lead' and 'pocket' referee (Table 1). Both referee roles had a significantly (moderate ES) higher $\%HR_{max}$ in the first half when compared to the second half ($P = 0.022$, $d = 0.60$; $P = 0.000$, $d = 0.76$ respectively).

****Insert Table 1 and 2 here****

Velocity Classifications

Table 3 displays the between ('lead' vs 'pocket') referee results, with Table 4 and 5 displaying the associated within ('lead' and 'pocket' independently) results. There were no significant differences ($P > 0.05$; small and trivial ES) between the 'lead' and 'pocket' referee in the mean distance and time at each movement velocity classification (Table 3).

****Insert Table 3 and 4 here****

Table 4 shows an overall significant difference ($P < 0.001$) and large to very large ES for distance covered and % distance between each velocity classification for both the 'lead' and 'pocket' referee. Where there were no significant differences there were moderate to large ES. Both referee roles covered the greatest distance (% distance) between 2.01 – 4.0 $m.s^{-1}$. Table 5 shows an overall significant difference ($P < 0.001$) and very large ES for time and % time between each velocity classification for both referee roles. Where there were no significant differences there were large ES. Both referee roles spent the most time (% time) < 2.01 $m.s^{-1}$.

****Insert Table 5 and 6 here****

There was a significant moderate difference between the 'lead' and 'pocket' in the number of efforts between 10 and 40m at a velocity greater than 7 $m.s^{-1}$ ($P = 0.044$, $d = 0.82$) (Table 6). There were no other significant differences in the mean frequency of movement efforts in total and by distance in each velocity classification. Both the 'lead' and 'pocket' referee performed the greatest number of efforts between 0.51 – 2.0 $m.s^{-1}$, with the number of efforts performed decreasing as the velocity increased. However, the number of efforts at velocities > 2.0 $m.s^{-1}$ increased in distance up to 40 m.

Discussion

This is the first study to evaluate the movement and physiological demands of the NRL 'two referee' officiating system and compare the demands of the respective roles using 10 Hz GPS devices. Therefore present findings, when compared to prior studies on NRL referees[7-9], can be considered as giving the most comprehensive and accurate analysis of the movement and physiological demands of NRL referees to date and the only research to assess the 'two referee' system, which can be used to inform conditioning programmes for these referees. A key finding of this study was that despite the differing roles of the 'lead' and 'pocket' referee, there were no differences in the movement and physiological demands between each role. This observation does not support the study's original hypothesis. There was one exception, with a higher number of efforts > 7

$m.s^{-1}$ between 10 m and 40 m performed by the 'lead' referee. However, these efforts equated to less than one effort per game for each referee, and as such has no real world meaning. This study has also re-affirmed the intermittent nature of rugby league refereeing at this elite standard, with the greatest distances and efforts performed at velocities <4.0 $m.s^{-1}$, interspersed with efforts >5.51 $m.s^{-1}$.

Both referee roles covered similar total distance to that previously reported on NRL referees by Hoare (7607 m) [9] but higher than those reported by Kay and Gill (6700 ± 400 m).[7] Most of the distance covered was between 0.51 – 4.0 $m.s^{-1}$ which is also similar to data reported for NRL referees.[9] The highest number of efforts were observed between 0.51 – 2.0 $m.s^{-1}$ with the distance of efforts increasing as the velocity increased (> 2.0 $m.s^{-1}$). This suggests that slow velocity efforts of short distance are interspersed with longer distance efforts at higher velocities (> 2.0 $m.s^{-1}$) demonstrating the intermittent nature of NRL referee movement demands. Assessing differences in the findings with other studies who have utilised different movement analysis systems should be done with caution, as prior studies have shown large between-system differences using video-based time-motion analysis systems, as well as 1 Hz and 5 Hz GPS systems.[19] Others have reported that an increase in sampling rate (5 Hz to 10 Hz) improves the validity and inter-unit reliability of GPS units [10], and that when compared to 1 Hz and 5 Hz GPS units, the 10 Hz GPS unit provides an improved measure of movement demands.[11]

There was no significant difference (small ES) for either the 'lead' or 'pocket' referee in relative distance covered between halves. However, both roles had a lower relative distance and covered a lower distance between 5.51 – 7.0 $m.s^{-1}$ in the 2nd half. NRL players have shown significantly lower relative distance in the 2nd half compared to the 1st half (2nd = 87.4 ± 8.8; 1st = 92.6 ± 9.4 $m.min^{-1}$).[2] Research has suggested that this decrease in the second half for elite rugby league players could be due to a change in tactics or the onset of fatigue.[20] As referees have to keep up with play at all times in order to minimise the possibility of an incorrect decision [21] the decrease in relative distance from the 1st half to the 2nd half could be explained by a reduction in the players actions or fatigue in referees, which is unclear at this stage. Future research assessing direct comparisons between elite rugby players and referees movement and physiological demands is warranted.

The mean heart rate values for the NRL 'lead' and 'pocket' referee were consistent with previous research on NRL referees.[8,9] Findings show that there was a significantly (moderate ES) lower $\%HR_{max}$ in the 2nd half in both the 'lead'

and 'pocket'. These findings are consistent with the lower relative distance covered in the 2nd half in both roles. There was no significant difference (small ES) between the NRL 'lead' and 'pocket' referee in the second half and in total $\%HR_{max}$, however there was a higher first half $\%HR_{max}$ (moderate ES) observed in the 'pocket' referee. Previous research has suggested that an increase in heart rate may be associated with factors other than the physiological demands of refereeing such as anxiety[8], stress[22] and experience[23]. In relation to the NRL referees the 'pocket' referee is the least experienced of the two referees and therefore further research analysing how experience and other factors may impact the physiological demands is required.

Practical Applications

Current findings allow those responsible for the training and conditioning of NRL referees to better understand the movement and physiological demands of the 'lead' and 'pocket' referee. Such information can enable practitioners to develop and enhance training programmes to ensure they reflect the specific physical match demands. As there were no role specific movement and physiological demand differences, similar training drills and conditioning programmes can be utilised, which may be beneficial when referees have to adopt both roles during a playing season. These findings can also enable aspiring referees to better understand the movement and physiological requirements of elite NRL referees to officiate at the highest level of domestic rugby league. This may include developing highly intermittent training activities including interspersing low intensity efforts with high intensity efforts (> 5.51 m.s^{-1}) of differing distances and intensities. To replicate, the physiological demands of refereeing conditioning programmes should include training which elicits an average heart rate of $\approx$ 84 $\%HR_{max}$.

Although there are currently no rugby league referee training research studies, high intensity intermittent running training has been reported to improve soccer referees fitness levels and therefore match performance.[21] A referee's weekly training programme should have a blend of high and low intensity aerobic sessions, as well as including sessions to improve running economy, repeat sprint ability and high-intensity intermittent endurance. A typical training week should aim to include 2-3 high intensity intermittent training sessions, which incorporates multi-directional movement to mimic the demands of the game.[24] It is important to note that when training referees, during a training week efforts that 'overload' the match demands should be included. This type of training will hopefully enable the rugby referee to keep up with play with reduced effort, allowing them the optimal viewing position, to make a correct decision.

Conclusions

This is the first study to evaluate the movement and physiological demands of NRL 'lead' and 'pocket' referees, officiating within the 'two referee' system using 10 Hz GPS devices. In comparing these referee roles, based on repeated measures of many referees across multiple rounds of NRL matches, no differences in the total distance, relative distance covered and $\%HR_{max}$ during match play were apparent. Likewise, there were no differences between the referee roles in the distance, percentage distance, time, percentage time and number of efforts, within all movement velocity classifications. Findings thus demonstrate the intermittent and similarity of on-field movement demands for NRL referees, regardless of referee role. Refereeing in either role at the professional elite level involves frequent changes of velocity of differing distances, with periods of low velocity efforts interspersed with short high velocity efforts.

Acknowledgements

The authors would like to thank the referees for their cooperation and efforts during all data collection procedures and would like to acknowledge the support of Stuart Cummings and the National Rugby League including Cameron Black in facilitating this research. The authors would also like to thank Perform Better and Catapult Sports for access to 10 Hz GPS devices in Australia.

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Table 1. Movement and Physiological Demands for the NRL 'Lead' and 'Pocket' Referee (mean ± sd and effect sizes).

	Lead Referee			Pocket Referee			Lead v Pocket Referee		
	1st Half	**2nd Half**	**Total**	**1st Half**	**2nd Half**	**Total**	**1st Half**	**2nd Half**	**Total**
Total Distance (m)	3746 ± 385	3681 ± 439	7427 ± 775	3811 ± 280	3799 ± 315	7610 ± 523	*P* = 0.628 *d* = 0.18	*P* = 0.441 *d* = 0.31	*P* = 0.487 *d* = 0.27
Relative Distance (m.min^{-1})	83.7 ± 7.4	79.8 ± 9.0	81.8 ± 7.6	85.6 ± 7.4	82.2 ± 6.9	83.9 ± 6.5	*P* = 0.528 *d* = 0.26	*P* = 0.460 *d* = 0.30	*P* = 0.450 *d* = 0.30
Average Heart Rate (% HR$_{max}$)	84.0 ± 2.6*	82.3 ± 3.1	83.0 ± 2.7	86.1 ± 3.7†	83.5 ± 3.2	84.7 ± 3.4	*P* = 0.142 *d* = 0.67	*P* = 0.373 *d* = 0.38	*P* = 0.223 *d* = 0.55

* indicates a significant difference between 1st and 2nd half for NRL lead referee ($P < 0.05$)
† indicates a significant difference between 1st and 2nd half for NRL pocket referee ($P < 0.001$)

Table 2. Distance at Each Movement Velocity Classification for the NRL 'Lead' and 'Pocket' Referee Independently (mean ± sd and effect sizes).

	Lead Referee			Pocket Referee		
	Total Distance (m)			**Total Distance (m)**		
Velocity	**1st Half**	**2nd Half**		**1st Half**	**2nd Half**	
< 0.5 m.s^{-1}	194 ± 170	181 ± 109	*P* = 0.545 *d* = 0.09	180.5 ± 103.4	209.6 ± 165.5	*P* = 0.310 *d* = 0.21
0.51-2.0 m.s^{-1}	1312 ± 80.1	1313 ± 121	*P* = 0.972 *d* = 0.01	1248 ± 81.7	1301 ± 62.4	*P* = 0.002 *d* = 0.73
2.01-4.0 m.s^{-1}	1650 ± 346	1663 ± 367	*P* = 0.840 *d* = 0.04	1784 ± 263	1761 ± 329	*P* = 0.658 *d* = 0.08
4.01-5.5 m.s^{-1}	481 ± 168	443 ± 166	*P* = 0.149 *d* = 0.23	494 ± 131	451 ± 163	*P* = 0.282 *d* = 0.29
5.51-7.0 m.s^{-1}	69.5 ± 41.3	58.7 ± 36.3	*P* = 0.192 *d* = 0.28	74.6 ± 46.8	51.3 ± 28.3	*P* = 0.068 *d* = 0.60
> 7.0 m.s^{-1}	8.4 ± 10.7	4.3 ± 6.3	*P* = 0.173 *d* = 0.47	3.6 ± 7.3	3.6 ± 9.4	*P* = 0.988 *d* = 0.01

Grey indicates a significant difference between 1st and 2nd half ($P < 0.05$)

Table 3: Distance and Time at Each Movement Velocity Classification for the NRL 'Lead' and 'Pocket' Referee (mean ± sd and effect sizes).

Velocity	Lead Referee				Pocket Referee				Lead v Pocket Referee			
	Distance (m)	**Distance (%)**	**Time (minutes)**	**Time (%)**	**Distance (m)**	**Distance (%)**	**Time (minutes)**	**Time (%)**	**Distance (m)**	**Distance (%)**	**Time (minutes)**	**Time (%)**
< 0.5 m.s^{-1}	374 ± 277	5.8 ± 5.6	33.6 ± 4.6	36.8 ± 5.3	390 ± 256	5.7 ± 4.5	33.5 ± 3.5	36.8 ± 3.3	*P* = 0.883 *d* = 0.06	*P* = 0.966 *d* = 0.02	*P* = 0.999 *d* = 0.02	*P* = 0.990 *d* = 0.00
0.51-2.0 m.s^{-1}	2627 ± 168	36.0 ± 4.2	34.1 ± 2.2	37.5 ± 2.6	2548 ± 137	34.1 ± 3.2	33.0 ± 2.1	36.3 ± 1.9	*P* = 0.213 *d* = 0.52	*P* = 0.210 *d* = 0.52	*P* = 0.194 *d* = 0.51	*P* = 0.173 *d* = 0.54
2.01-4.0 m.s^{-1}	3311 ± 680	43.8 ± 6.2	19.0 ± 3.8	21.0 ± 4.0	3545 ± 562	45.8 ± 5.4	20.1 ± 3.0	22.2 ± 3.3	*P* = 0.356 *d* = 0.39	*P* = 0.405 *d* = 0.35	*P* = 0.397 *d* = 0.32	*P* = 0.387 *d* = 0.33
4.01-5.5 m.s^{-1}	922 ± 325	12.0 ± 3.4	3.4 ± 1.2	3.7 ± 1.3	945 ± 258	12.0 ± 2.8	3.5 ± 0.9	3.9 ± 1.2	*P* = 0.846 *d* = 0.08	*P* = 0.991 *d* = 0.00	*P* = 0.949 *d* = 0.10	*P* = 0.680 *d* = 0.17
5.51-7.0 m.s^{-1}	129 ± 72.6	1.7 ± 0.9	0.4 ± 0.2	0.4 ± 0.5	126 ± 63.6	1.6 ± 0.7	0.4 ± 0.2	0.3 ± 0.4	*P* = 0.912 *d* = 0.04	*P* = 0.642 *d* = 0.19	*P* = 0.917 *d* = 0.09	*P* = 0.543 *d* = 0.25
> 7.0 m.s^{-1}	12.7 ± 14.8	0.1 ± 0.3	0.0 ± 0.0	0.0 ± 0.0	7.2 ± 12.5	0.1 ± 0.2	0.0 ± 0.0	0.0 ± 0.0	*P* = 0.327 *d* = 0.40	*P* = 0.989 *d* = 0.00	*P* = 0.261 *d* = 0.52	

Table 4: Difference and Effect Sizes in Distance and % Distance at Each Movement Velocity Classification for the NRL 'Lead' and 'Pocket' Referee Independently

Velocity	Distance						% Distance					
	< 0.5m.s^{-1}	**0.51-2.0m.s^{-1}**	**2.01-4.0m.s^{-1}**	**4.01-5.5m.s^{-1}**	**5.51-7.0m.s^{-1}**	**> 7.0m.s^{-1}**	**< 0.5m.s^{-1}**	**0.51-2.0m.s^{-1}**	**2.01-4.0m.s^{-1}**	**4.01-5.5m.s^{-1}**	**5.51-7.0m.s^{-1}**	**> 7.0m.s^{-1}**
< 0.5m.s^{-1}		***P* < 0.001** ***d* = 9.85**	***P* < 0.001** ***d* = 5.66**	*P* = 0.107 *d* = 1.82	*P* = 0.369 *d* = 1.21	***P* = 0.023** ***d* = 1.84**		***P* < 0.001** ***d* = 6.13**	***P* < 0.001** ***d* = 6.44**	*P* = 0.425 *d* = 1.34	*P* = 0.702 *d* = 1.01	*P* = 0.109 *d* = 1.43
0.51-2.0m.s^{-1}	***P* < 0.001** ***d* = 10.52**		*P* = 0.086 *d* = 1.37	***P* < 0.001** ***d* = 6.60**	***P* < 0.001** ***d* = 19.3**	***P* < 0.001** ***d* = 21.95**	***P* < 0.001** ***d* = 7.29**		*P* = 0.293 *d* = 1.48	***P* < 0.001** ***d* = 6.33**	***P* < 0.001** ***d* = 11.37**	***P* < 0.001** ***d* = 12.17**
2.01-4.0m.s^{-1}	***P* < 0.001** ***d* = 7.24**	***P* < 0.001** ***d* = 2.45**		***P* < 0.001** ***d* = 4.48**	***P* < 0.001** ***d* = 6.58**	***P* < 0.001** ***d* = 6.86**	***P* < 0.001** ***d* = 8.09**	**p = 0.001** ***d* = 2.66**		***P* < 0.001** ***d* = 6.37**	***P* < 0.001** ***d* = 9.51**	***P* < 0.001** ***d* = 9.97**
4.01-5.5m.s^{-1}	***P* = 0.009** ***d* = 2.16**	***P* < 0.001** ***d* = 7.77**	***P* < 0.001** ***d* = 5.96**		***P* < 0.001** ***d* = 3.37**	***P* < 0.001** ***d* = 3.95**	*P* = 0.053 *d* = 1.67	***P* < 0.000** ***d* = 7.39**	***P* < 0.001** ***d* = 7.89**		***P* < 0.001** ***d* = 4.13**	***P* < 0.001** ***d* = 4.94**
5.51-7.0m.s^{-1}	***P* = 0.043** ***d* = 1.42**	***P* < 0.001** ***d* = 22.7**	***P* < 0.001** ***d* = 8.56**	***P* < 0.001** ***d* = 4.36**		***P* = 0.003** ***d* = 2.22**	*P* = 0.074 *d* = 1.28	***P* < 0.000** ***d* = 14.22**	***P* < 0.001** ***d* = 11.56**	***P* < 0.001** ***d* = 5.07**		***P* = 0.002** ***d* = 2.28**
> 7.0m.s^{-1}	***P* < 0.001** ***d* = 2.11**	***P* < 0.001** ***d* = 26.14**	***P* < 0.001** ***d* = 8.91**	***P* < 0.001** ***d* = 5.13**	***P* = 0.003** ***d* = 2.59**		***P* = 0.005** ***d* = 1.75**	***P* < 0.001** ***d* = 15.23**	***P* < 0.001** ***d* = 12.05**	***P* < 0.001** ***d* = 5.95**	***P* < 0.001** ***d* = 2.65**	

Grey indicates lead referee data / No shading indicates the pocket referee Bold text indicates a significant difference / *d* = Cohen's *d* effect size

Table 5: Differences and Effect Sizes in Time and % Time at Each Movement Velocity Classification for the NRL 'Lead' and 'Pocket' Referee Independently

	Time						% Time					
Velocity	**< 0.5m.s^{-1}**	**0.51-2.0m.s^{-1}**	**2.01-4.0m.s^{-1}**	**4.01-5.5m.s^{-1}**	**5.51-7.0m.s^{-1}**	**> 7.0m.s^{-1}**	**< 0.5m.s^{-1}**	**0.51-2.0m.s^{-1}**	**2.01-4.0m.s^{-1}**	**4.01-5.5m.s^{-1}**	**5.51-7.0m.s^{-1}**	**> 7.0m.s^{-1}**
< 0.5m.s^{-1}		p = 1.000 *d* = 0.14	**p = 0.002** ***d* = 3.45**	***P* < 0.001** ***d* = 8.98**	***P* < 0.001** ***d* = 10.16**	***P* < 0.001** ***d* = 10.27**		*P* = 1.000 *d* = 0.17	***P* = 0.003** ***d* = 3.40**	***P* < 0.001** ***d* = 8.65**	***P* < 0.001** ***d* = 9.76**	***P* < 0.001** ***d* = 9.91**
0.51-2.0m.s^{-1}	*P* = 1.000 *d* = 0.17		***P* < 0.001** ***d* = 4.86**	***P* < 0.001** ***d* = 17.49**	***P* < 0.001** ***d* = 21.60**	***P* < 0.001** ***d* = 21.90**	*P* = 1.000 *d* = 0.19		***P* < 0.001** ***d* = 4.96**	***P* < 0.001** ***d* = 16.62**	***P* < 0.001** ***d* = 20.13**	***P* < 0.001** ***d* = 20.72**
2.01-4.0m.s^{-1}	***P* < 0.001** ***d* = 4.09**	***P* < 0.001** ***d* = 4.95**		***P* < 0.001** ***d* = 5.57**	***P* < 0.001** ***d* = 6.93**	***P* < 0.001** ***d* = 7.06**	***P* < 0.001** ***d* = 4.44**	***P* < 0.001** ***d* = 5.32**		***P* < 0.001** ***d* = 5.88**	***P* < 0.001** ***d* = 7.31**	***P* < 0.001** ***d* = 7.52**
4.01-5.5m.s^{-1}	***P* < 0.001** ***d* = 11.75**	***P* < 0.001** ***d* = 18.24**	***P* < 0.001** ***d* = 7.44**		***P* < 0.001** ***d* = 3.59**	***P* < 0.001** ***d* = 4.04**	***P* < 0.001** ***d* = 13.16**	***P* < 0.001** ***d* = 20.72**	***P* < 0.001** ***d* = 7.44**		***P* < 0.001** ***d* = 3.31**	***P* < 0.001** ***d* = 3.99**
5.51-7.0m.s^{-1}	***P* < 0.001** ***d* = 13.38**	***P* < 0.001** ***d* = 21.92**	***P* < 0.001** ***d* = 9.20**	***P* < 0.001** ***d* = 4.71**		**p = 0.003** ***d* = 2.32**	***P* < 0.001** ***d* = 15.42**	***P* < 0.001** ***d* = 26.86**	***P* < 0.001** ***d* = 9.42**	***P* < 0.001** ***d* = 3.97**		*P* = 0.185 *d* = 1.30
> 7.0m.s^{-1}	***P* < 0.001** ***d* = 13.53**	***P* < 0.001** ***d* = 22.21**	***P* < 0.001** ***d* = 9.37**	***P* < 0.001** ***d* = 5.30**	***P* < 0.001** ***d* = 2.79**		***P* < 0.001** ***d* = 15.68**	***P* < 0.001** ***d* = 27.75**	***P* < 0.001** ***d* = 9.63**	***P* < 0.001** ***d* = 4.57**	*P* = 0.129 *d* = 1.17	

Grey indicates lead referee data / No shading indicates the pocket referee Bold text indicates a significant difference / *d* = Cohen's *d* effect size

Table 6: Frequency of Movement Efforts in Total and by Distance in Each Velocity Classification for the NRL 'Lead' and 'Pocket' Referee (mean ± sd and effect sizes).

	Lead Referee					Pocket Referee					Lead v Pocket Referee				
Velocity	**Total**	**0-5 m**	**5-10 m**	**10-40 m**	**40 m+**	**Total**	**0-5 m**	**5-10 m**	**10-40 m**	**40 m+**	**Total**	**0-5 m**	**5-10 m**	**10-40 m**	**40 m+**
0.51-2.0 m.s^{-1}	395 ± 17.0	221 ± 21.3	108 ± 11.1	64.9 ± 10.1	1.2 ± 0.7	393 ± 30.5	227 ± 32.5	105 ± 9.5	61.3 ± 8.6	1.4 ± 1.3	*P* = 0.898 *d* = 0.08	*P* = 0.655 *d* = 0.22	*P* = 0.465 *d* = 0.30	*P* = 0.343 *d* = 0.39	*P* = 0.649 *d* = 0.18
2.01-4.0 m.s^{-1}	231 ± 36.7	27.5 ± 6.3	74.5 ± 14.3	122 ± 28.7	7.8 ± 4.5	233 ± 26.0	27.0 ± 10.1	70.7 ± 14.7	125 ± 20.2	9.8 ± 4.8	*P* = 0.927 *d* = 0.06	*P* = 0.882 *d* = 0.06	*P* = 0.522 *d* = 0.26	*P* = 0.729 *d* = 0.12	*P* = 0.285 *d* = 0.44
4.01-5.5 m.s^{-1}	65.2 ± 22.7	4.27 ± 2.4	19.6 ± 7.2	40.8 ± 14.2	0.5 ± 0.4	66.5 ± 15.3	4.8 ± 1.7	22.1 ± 5.2	38.5 ± 8.9	1.1 ± 1.0	*P* = 0.863 *d* = 0.07	*P* = 0.533 *d* = 0.25	*P* = 0.308 *d* = 0.40	*P* = 0.627 *d* = 0.19	*P* = 0.119 *d* = 0.69
5.51-7.0 m.s^{-1}	7.8 ± 5.0	0.0.± 0.0	2.6 ± 2.5	5.1 ± 2.9	0.1 ± 0.2	7.1 ± 3.4	0.0 ± 0.0	2.1 ± 1.9	4.8 ± 2.3	0.2 ± 0.4	*P* = 0.686 *d* = 0.16		*P* = 0.591 *d* = 0.22	*P* = 0.783 *d* = 0.11	*P* = 0.506 *d* = 0.28
> 7.0 m.s^{-1}	0.6 ± 0.7	0.0 ± 0.0	0.1 ± 0.2	0.6 ± 0.7	0.0 ± 0.0	0.3 ± 0.6	0.0 ± 0.0	0.1 ± 0.3	0.1 ± 0.3	0.1 ± 0.2	*P* = 0.201 *d* = 0.53		*P* = 0.839 *d* = 0.08	*P* = 0.044 *d* = 0.82	*P* = 0.118 *d* = 0.64
Total	700 ± 72.1	253 ± 22.6	204 ± 22.9	233 ± 46.1	9.65 ± 4.2	700 ± 56.9	258 ± 39.9	200 ± 21.5	230 ± 30.6	12.6 ± 5.3	*P* = 0.996 *d* = 0.00	*P* = 0.707 *d* = 0.15	*P* = 0.600 *d* = 0.18	*P* = 0.838 *d* = 0.08	*P* = 0.148 *d* = 0.62

Grey indicates a significant difference between NRL lead and pocket referee (P < 0.05)